Active Power Control in Wind Parks

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Siemens Wind Turbines - Americas

What Are Common Active Power Control Requirements in the US?

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Existing:

- Power Output (Curtailment) Control

- Ramp Rate Control
  - Curtailments
  - Start-up

- Regulation Up for Underfrequency
  - Adjustable Droop

- Regulation Down for Overfrequency
  - Adjustable Droop

- High Wind Shutdown

- Rate Variation Control

Expectation for New Requirements
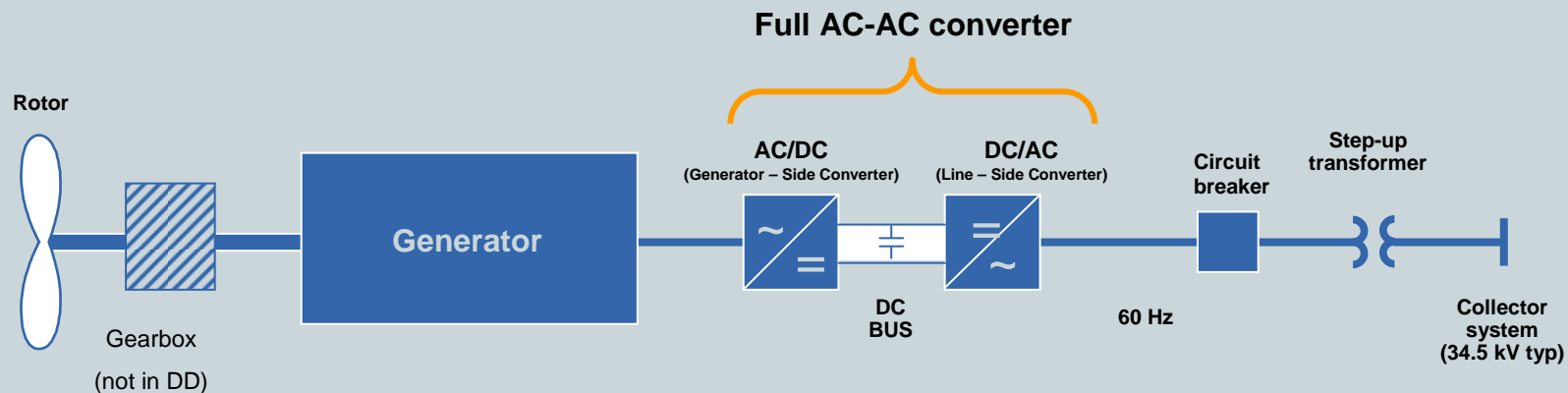
Expected in the next 5 years:

- Automatic Generation Control (AGC) participation

- Spinning Reserve ("Delta" Control)
  - Frequency Responsive
  - Remote

- Transient Underfrequency ("Inertial") Response

Type 4 Variable Speed Full Converter WTG
Basic operation – typical configuration

Full AC-AC converter

Rotor

AC/DC
(Generator – Side Converter)

DC/AC
(Line – Side Converter)

Circuit breaker

Step-up transformer

Generator

DC BUS

60 Hz

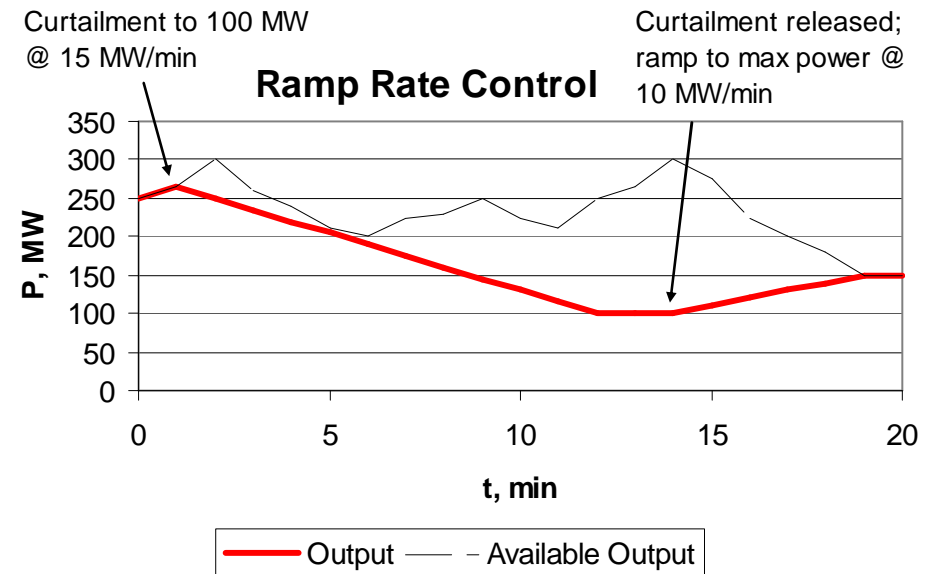Collector system (34.5 kV typ)

Gearbox

(not in DD)

- **Rotor drives gearbox in geared systems. Gearbox eliminated in DD (direct drive); rotor directly drives low-speed, multi-pole generator**

- **Generator converts mechanical power to AC electric power. Generator can be asynchronous, permanent magnet or synchronous for geared system, pm or synchronous for DD.**

- **Generator-side converter converts AC electric power to DC**

- **Line-side converter converts DC to system-frequency AC (50 Hz or 60 Hz, as appropriate) and provides voltage regulation capability**

- **Can control real and reactive power output from line-side converter – rapid, precise control.**

Ramp Rate Control - Smooth, Controlled Transition from One Output Level to Another

Some ISOs (e.g., ERCOT, some Canadian provinces) require ramp rate control to smoothly transition from one output level to another during curtailments.

- Can select any ramp rate slower than ~10%/sec, assuming availability of adequate wind power

- Typical ramp requirement is 10% per minute or slower.

Curtailment to 100 MW @ 15 MW/min

Curtailment released; ramp to max power @ 10 MW/min

Ramp Rate Control

P, MW

t, min

Output — – Available Output

Frequency Droop Control

Some ISO/RTOs require the use of frequency droop response from wind parks

- Normally constant (5%) frequency droop (5% change in freq → 100% change in output), but variable droop sometimes required (e.g., larger droop for small frequency excursions, smaller droop for larger excursions).

- Both reg up (underfreq), assuming curtailed state, and reg down (overfrequency) required.

- Sometimes conflicts w/ curtailments, SPS operations.

- Controls compatible with ERCOT protocols.

Frequency Droop Response
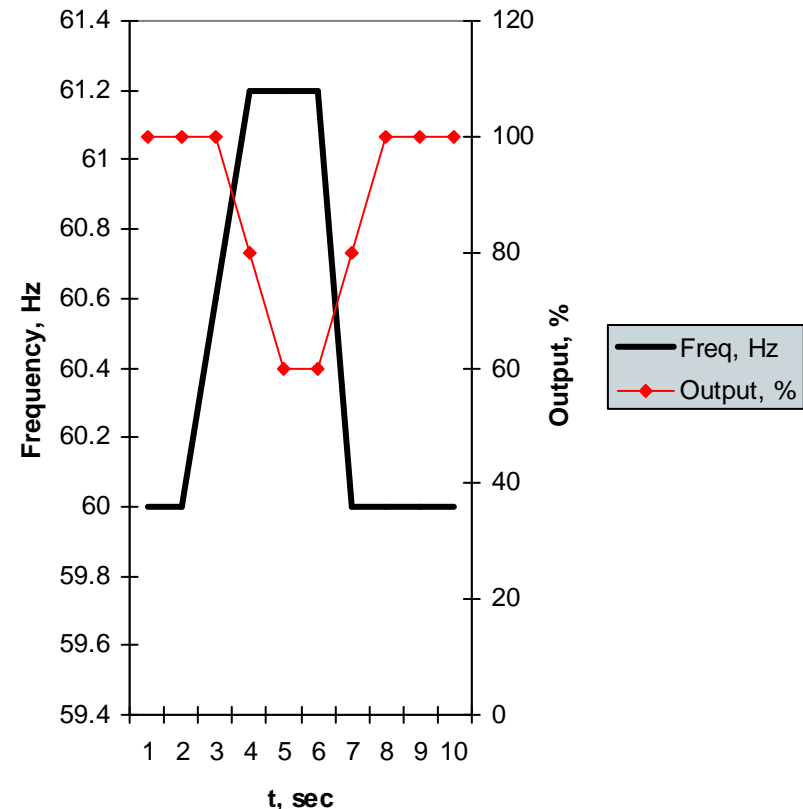
Recent Field Test Results – Regulation Down
Demonstrating Frequency Regulation for Overfrequency

Recent results from test of "frequency control sensitive mode" (proportional droop response) – required by UK grid

**Turbines at reference power**   **Fast frequency increase**   **Increase in turbine output power**

Reduction in Turbine Output Power
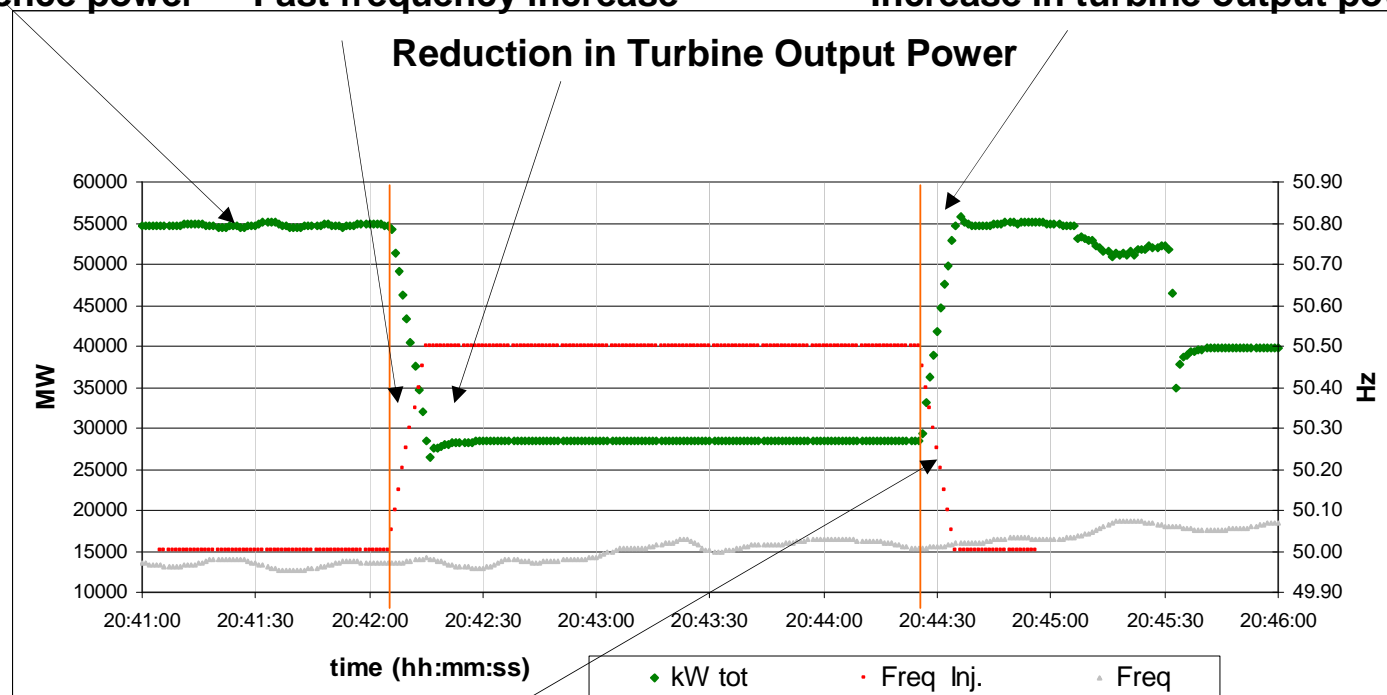
Fast frequency recovery

Recent Field Test Results – Regulation Up
Demonstrating Frequency Regulation for Underfrequency

Recent results from test of "frequency control sensitive mode" (proportional droop response) – required by UK grid

Increase in turbine output power

Turbines at reduced power

Reduction in turbine output power

Sudden frequency reduction

Sudden frequency recovery
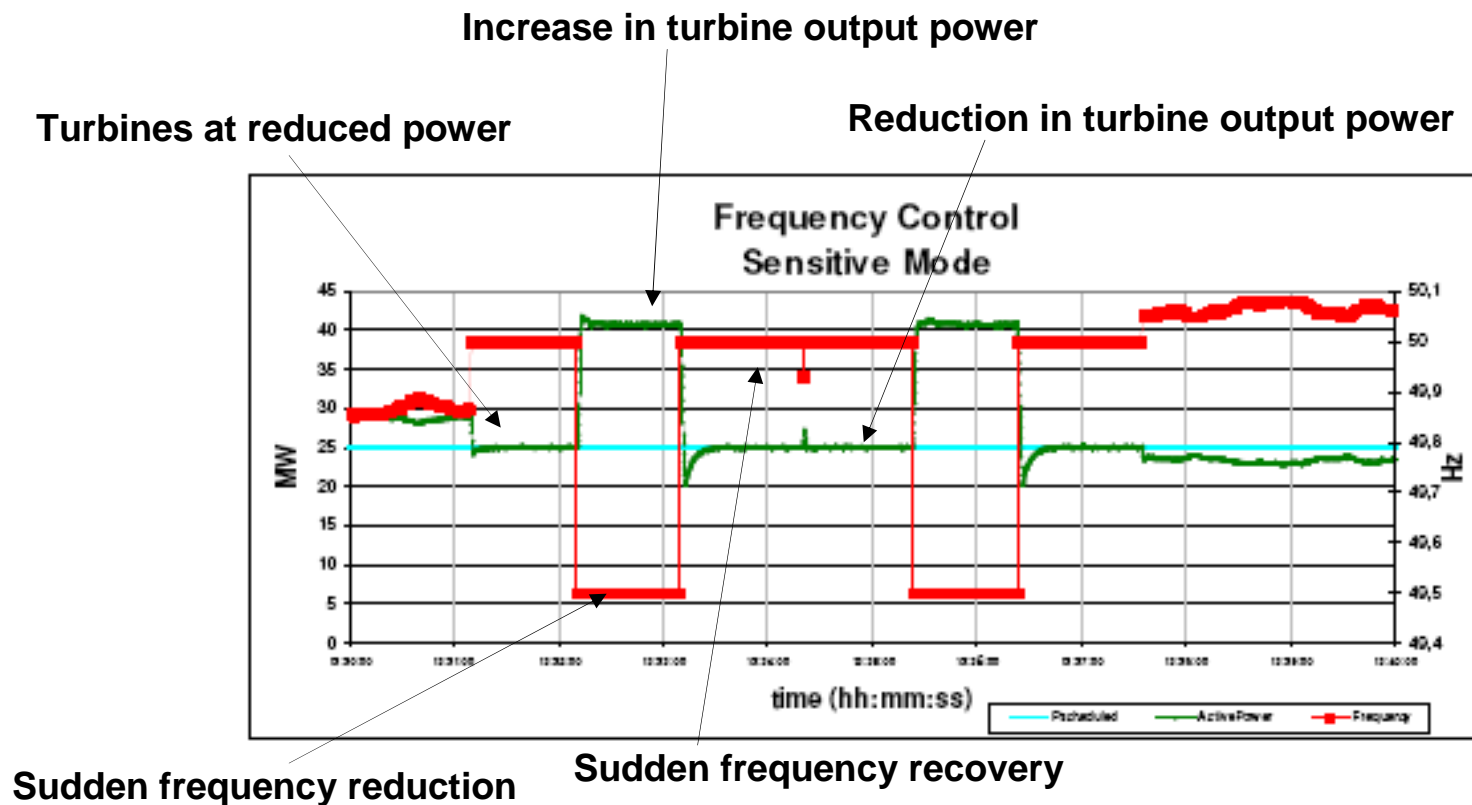
High Wind Shutdown – What is it?

Ramp-down of power in anticipation of high-wind speed trip.

Reduces power loss and resulting frequency reduction caused by weather fronts.

High Wind Shutdown
10 m/s rated speed, trip @ 25 m/s
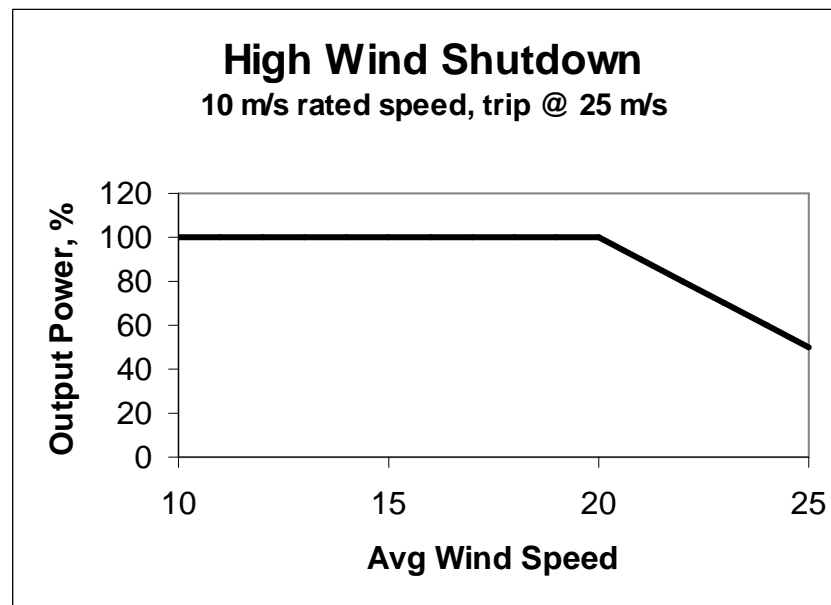
Rate Variation Control

Control of output power change, e.g., "no more than 10% change per minute"

Since electric power varies as cube of wind speed, rate variation control requires operation at reduced output power levels during conditions when wind speed varies or use of energy storage.

Controls typically assume persistence and use recent history to set output.

Seldom used.
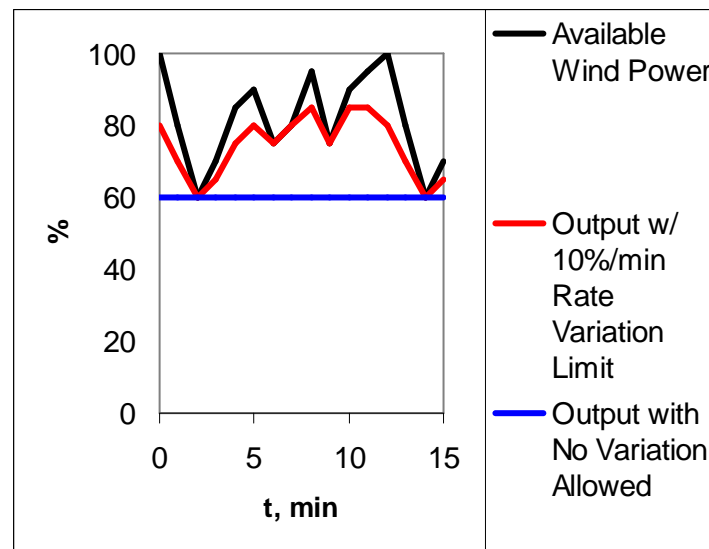
Delta Control – Operate with a Constant Delta Below Maximum Output

Some ISOs are considering the use of wind for regulation up and spinning reserve duty at some times of the day to release fossil capacity.

- Requires "spilling wind," but may be the least expensive way to provide capability

- Can select any delta (MW) assuming availability of adequate wind power

Delta Control (50 MW delta)

Legend: Available Output — Actual Output

X-axis: t, min (0, 5, 10, 15, 20)
Y-axis: P, MW (0, 50, 100, 150, 200, 250, 300)
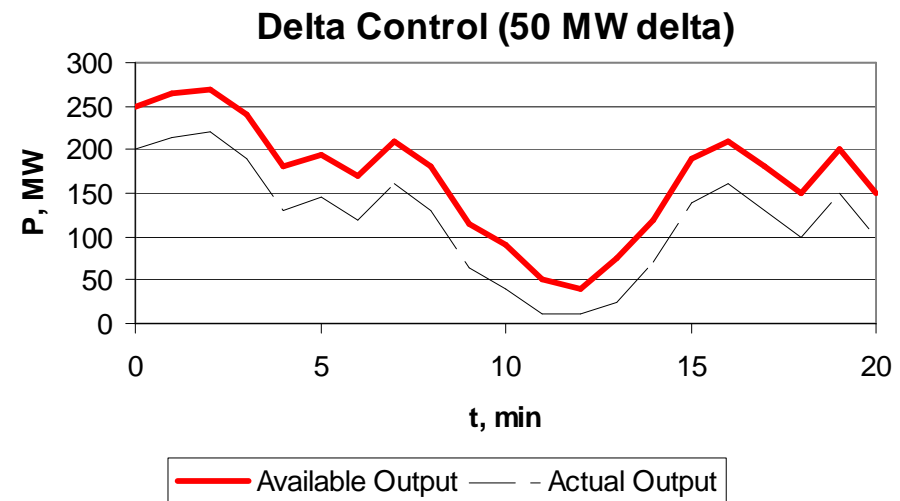
Transient Under-Frequency Response ("inertial response")

Rapid injection of energy required after sudden frequency drop – useful to forestall load shedding and generator tripping, especially on island systems.

Sometimes called "inertial response" because synchronous generators provide this energy from shaft KE.

Converter-controlled WTGs do not provide this function naturally, but can be programmed to provide it.

Wind turbines have substantial inertia in rotor – could be exercised to provide a short-term power boost. Energy storage could be used, too.

Under development and testing.

Preliminary simulations for 20% wind case with different transient controls
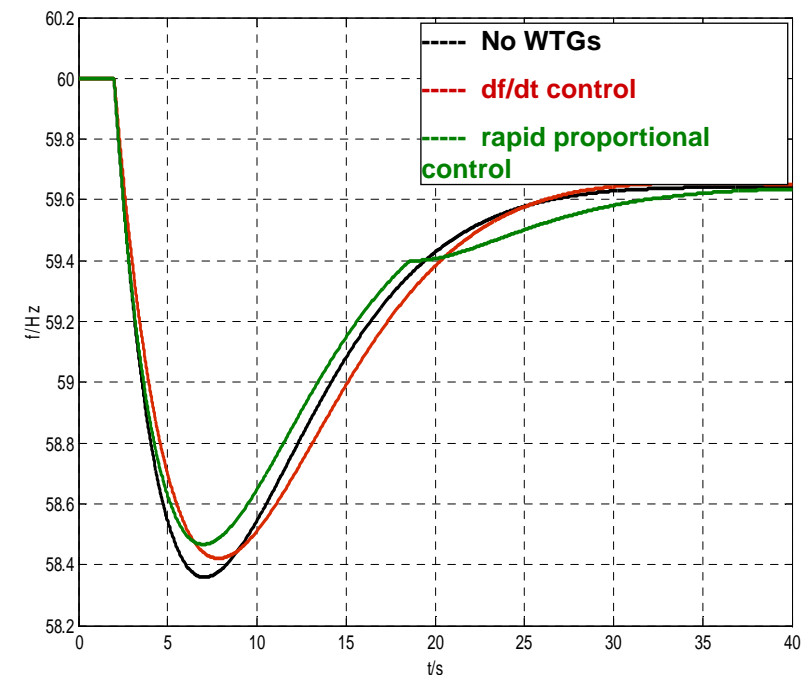
Automatic Generation Control (AGC) – What is it?

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- Slow control (30 sec typical); small adjustments to maintain Area Control Error (including tie line flows) within limits.

- Can be used to supplement P-command from Park RTU.

- No clear reason to include separately in wind park controls, since wind parks are capable of very fast response (few sec for typical output response, if no ramp rate restrictions are imposed).

Summary – How Siemens WTGs provide Power Control
(existing and anticipated)

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Capability	Now	Soon
Power Output (Curtailment) Control	✿	
Ramp-Rate Control (ref change and startup)	✿	
Frequency Droop Regulation Up	✿	
Frequency Droop Regulation Down	✿	
Frequency-Dependent Droop	✿	
Spinning reserve ("delta control") capability	✿	
Transient underfrequency ("inertial") response		✿
High wind shutdown	✿	
AGC Response (from Park RTU)	✿	
Rate Variation Control	✿	

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Questions?

Thank You!